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TITLE: **VISUAL PROSTHESIS INCLUDING ENHANCED RECEIVING AND STIMULATING PORTION**

INVENTOR:

FIELD OF THE INVENTION

This invention relates generally to a visual prosthesis for restoring at least partial vision to a user afflicted with photoceptor degeneration.

BACKGROUND OF THE INVENTION

U.S. Patent 5,935,155 describes a visual prosthesis generally comprised of (1) an image acquiring and transmitting portion and (2) a receiving and retina stimulating portion. The acquiring portion includes a camera for generating a visual signal output representative of an acquired image. The stimulating portion includes an electrode array adapted to be operatively attached to the user's retina. The visual signal output is used to modulate a radio frequency (RF) carrier signal which is applied to a primary coil. A secondary coil receives the RF signal which is then demodulated to recover the visual signal output for driving the electrode array to electrically stimulate retinal tissue. In use, the acquiring and transmitting portion is mounted outside of the eye (extraocular) and the receiving and stimulating portion is primarily mounted in the eye (intraocular) The components of the intraocular portion are powered from energy extracted from the transmitted visual signal.

Figure 1 of Patent 5,935,155 comprises a functional block diagram of the visual prosthesis showing its image acquiring and transmitting portion and its receiving and retina stimulating portion. Figures 2 and 3 respectively show the organization of functional components of the respective portions of Figure 1. Figures 4, 5, and 6 depict alternative arrangements for deploying the prosthesis physical components. In all of the figures, the primary coil is mounted in alignment with the optic axis in front of the eye, e.g., in an eyeglass lens, frame, or in a soft contact lens. In Figure 4, the secondary coil is implanted behind the iris and a circuit housing is collocated therewith. In Figure 5, the secondary coil is implanted behind the iris but the circuit housing is located outside of the sclera wall.

In Figure 6, the secondary coil is placed adjacent the outer sclera surface. U.S. Patents 5,800,530 and 6,120,538 describe alternative visual prostheses.

SUMMARY OF THE INVENTION

The present invention is directed to a visual prosthesis and more particularly to an enhanced receiving and stimulating portion for electrically stimulating retinal tissue to present an apparent image to a user. Visual prosthesis embodiments in accordance with the invention utilize an image acquiring and transmitting portion having an extraocular camera and primary coil. The camera responds to a real image to generate a real image signal which is coupled, e.g., RF coupling, from the primary coil to the secondary coil of the receiving and stimulating portion.

In accordance with a firs preferred embodiment of the invention, the secondary coil is placed within the vitreous body of the user's eye positioned and oriented for good signal coupling to the extraocular primary coil. For example, both coils are located in close proximity substantially coincident with the optic axis of the user's eye. Moreover, the secondary coil is arranged to be in good thermal contact with the vitreous body which acts as a heat sink.

In accordance with a significant aspect of the first preferred embodiment, a signal processing circuitry electrically connected to the secondary coil is also placed in the vitreous body to assure efficient heat transfer therefrom. The circuitry is preferably contained in a protective hermetically sealed housing which preferably comprises a metal can but which also can constitute any coating or envelope for protecting the circuitry from adverse effects of salt water. The circuitry responds to an output signal from the secondary coil to produce an apparent image signal for driving an electrode array. The electrode array is configured to electrically stimulate the eye's retinal tissue to enable a user to perceive an apparent image.

In accordance with a further feature of the preferred embodiment, the housing, which is preferably metal, is placed and/or oriented in a manner to minimize the generation of eddy currents in the housing wall which would diminish energy transmission efficiency. In one arrangement, the housing is located posteriorly of the secondary coil but oriented with its shortest dimensions

perpendicular to the secondary coil axis. In an alternative arrangement, the housing is displaced from the secondary coil axis but in substantially the same plane as the secondary coil.

In a still further embodiment the invention, the housing is placed outside the sclera wall and electrically connected through the sclera to the secondary coil and retina electrode array.

In accordance with a still further prosthesis embodiment, the primary coil and secondary coil are both located to the side of the optic axis outside of the sclera wall enabling them to be closely coupled. The circuit housing is preferably located very close to the secondary coil and is electrically connected through the sclera to the retina electrode array.

BRIEF DESCRIPTION OF THE FIGURES

Figure 1 is a functional block diagram of the visual prosthesis described in US Patent 5935155 showing its (1) image acquiring and transmitting portion and its (2) receiving and retina stimulating portion;

Figures 2 and 3 are functional block diagrams respectively showing the organization of the (1) image acquiring and transmitting portion and the (2) receiving and retina stimulating portion.

Figure 4 depicts a simplified cross-section of an eye showing the placement of receiving and stimulating components in accordance with a first embodiment of the present invention;

Figure 5 depicts a simplified cross-section of an eye showing the placement of receiving and stimulating components in accordance with a second embodiment of the present invention;

Figure 6 depicts a simplified cross-section of an eye showing the placement of receiving and stimulating components in accordance with a third embodiment of the present invention; and

Figure 7 depicts a simplified cross-section of an eye showing the placement of receiving and stimulating components in accordance with a fourth embodiment of the present invention.

DETAILED DESCRIPTION

Figure 1 depicts the visual prosthesis 10 of US Patent 5935155 which includes an image capturing element, such as a standard charge coupled device (CCD) camera 12, whose output is processed and encoded in circuit block 14. This processed and encoded captured real image signal is then coupled via primary coil 16 to a secondary coil 18. For example, the real image signal can be transmitted as a modulated radio frequency (RF) carrier signal. The secondary coil 18 receives the real image signal and applies an output signal to the signal processing circuit block 20. This circuit block 20 decodes and demultiplexes the applied signal and then communicates an apparent image signal to an electrode array 22 which stimulates the retinal cells to produce phoshenes in a pattern to simulate vision.

It should be noted that the dashed line 24 in FIG. 1 is included to functionally separate the image acquiring and transmitting portion 26 from the image receiving and stimulating portion 28 of the visual prosthesis 10. The dashed line 24 may or may not indicate the physical separation of extraocular and intraocular components as will be described more fully hereinafter with reference to FIGS. 4-7.

The image acquiring and transmitting portion 26 of the visual prosthesis 10 is illustrated in greater detail in FIG. 2 which shows the output of camera 12 coupled to an image sampler circuit 30 whose output is passed to a pixel encoder 32. The output of encoder 32 is passed to a signal modulator 34 which modulates a radio frequency carrier signal generated by the carrier generator 36. This RF signal is then applied to the primary coil 16.

The encoding scheme is preferably optimized for the target image resolution which is primarily determined by the size of the implanted electrode array.

The encoded information typically includes such parameters as the magnitude, timing, and sequence of the stimulation pulses which will be generated by the electrode array to simulate the image through retinal stimulation.

The RF signal applied to primary coil 16 is received by the secondary coil 18 of the stimulating portion 28 as illustrated in greater detail in FIG. 3. The secondary coil 18 output is passed to the demodulator 38 where the RF carrier

signal is removed and the encoded image signal recovered. The encoded image signal is then passed to a decoder/demultiplexer 40 which in turn outputs the image information to a current generator 42 which drives the individual electrodes of the electrode array 22. The electric power for components of the image receiving and stimulating portion 28 is derived from the energy contained in the coupled RF signal through rectifier 44.

Attention is now directed to Figure 4 which depicts a first embodiment of the invention in which all of the components of the receiving and retina stimulating portion 28 are implanted in the vitreous chamber 50 of a user's eye 51. The chamber 50 is filled with the vitreous body 52 which comprises a clear colorless transparent jelly. As depicted in Figure 4, the secondary coil 18 is fixed, e.g., by suture 53 to the adjacent sclera wall 54, just behind the lens 56. The secondary coil 18 is preferably axially aligned with the extraocular primary coil 16 and the optic axis of the eye. The respective coils are preferably mounted so that their planes are oriented substantially parallel to one another to achieve good signal coupling. The secondary coil 18 is physically and electrically connected 58 to signal processing circuitry 20 mounted in housing 60 which preferably comprises a metal can but which can constitute any coating or envelope capable of providing protection from the deleterious effects of salt water. The circuitry 20 in housing 60 is connected via conductor 62 to a flexible electrode array 22 physically and electrically contacting the user's retina 64.

It is significant to note that the secondary coil 18, housing 60 and electrode array 22 are all mounted in the vitreous body 52 in good thermal contact therewith.

Thus, the vitreous body acts as a heat sink to cool the coil and electronic circuitry enabling the system to more efficiently utilize the signal energy derived from primary coil 16.

The housing 60 preferably comprises a hermetically sealed metal container having perpendicular width, depth, and length dimensions. In order to minimize eddy current induction into the housing wall, it is preferable to orient the housing with its smallest dimensions oriented parallel to the plane of coil 18 and preferably displaced from the coil axis.

Attention is now directed to Figure 5 which differs from Figure 4 in that housing 60 is placed to the side of coil 18 where it is fixed to the adjacent sclera wall, rather than hanging in the vitreous body as shown in Figure 4. The arrangement of Figure 5 offers greater mechanical stability and robustness than is available in Figure 4.

Figure 6 depicts a further embodiment in which the housing 60 is affixed to the extraocular side of the adjacent sclera wall. This housing placement has the advantage that essentially no eddy currents will be induced in the housing wall. Although housing placement is somewhat simplified relative to Figures 4 and 5, it nevertheless requires that conductive leads from the secondary coil and to the electrode array be passed through the sclera wall.

Figure 7 depicts a further alternative embodiment in which the housing 60 is mounted off-axis adjacent to the extraocular side of the adjacent sclera wall with the secondary coil 18 being wound around the housing. This collocation of housing and secondary coil offers the potential for miniaturization. Moreover, the off-axis placement of the secondary coil 18 enables the primary coil 16 to be mounted off-axis and in alignment as shown in Figure 7. This off-axis placement may permit the coils 16, 18 to be placed closer together to increase signal coupling therebetween and the efficiency of the wireless transmission. As in Figure 6, the arrangement of Figure 7 requires that conductive leads pass through the sclera wall for connection to the electrode array 22.

From the foregoing, it should now be appreciated that several enhanced prosthesis embodiments have been described characterized by one or more of the following features:

1 - secondary coil mounted within the vitreous body;

2 - circuitry housing mounted within the vitreous body;

3 - secondary coil and circuitry housing collocated outside of the sclera wall displaced from the optic axis.

Although only a limited number of embodiments have been specifically described, it is recognized that various modifications and alternatives will occur to those skilled in the art which fall within the spirit and scope of the invention as defined by the appended claims.